



2007 Cayman Island Twilight Zone Expedition

What's Down There?

(adapted from the 2006 Laser Line Scan Expedition)

FOCUS

Mapping Coral Reef Habitats

GRADE LEVEL

9-12 (Life Science/Earth Science)

FOCUS QUESTION

What type of data do scientists collect to monitor coral reefs, and how are these data used?

LEARNING OBJECTIVES

Students will be able to access data on selected coral reefs and manipulate these data to characterize these reefs.

Students will be able to explain the need for baseline data in coral reef monitoring programs.

Students will be able to identify and explain five ways that coral reefs benefit human beings.

Students will be able to identify and explain three major threats to coral reefs.

MATERIALS

- Copies of "Coral Habitat Data Worksheet," one copy for each student group
- Copies of "Habitat Analysis Grid" photocopied onto transparencies; one for each student group

AUDIO/VISUAL MATERIALS

- None

TEACHING TIME

One 45-minute class period, plus time for student research

SEATING ARRANGEMENT

Groups of 3-4 students

MAXIMUM NUMBER OF STUDENTS

32

KEY WORDS

Deep-water coral
Coral reef
Monitoring
Benthic habitat

BACKGROUND INFORMATION

Coral reefs provide habitats for some of the most diverse biological communities on Earth. Most people have seen photographs and video images of shallow-water coral reefs, and many have visited these reefs in person. Historically, scientists have believed that reef-building corals were confined to relatively shallow depths because many of these corals have microscopic algae called zooxanthellae (pronounced "zoh-zan-THEL-ee") living inside their soft tissues. These algae are often important for the corals' nutrition and growth, but require sunlight for photosynthesis. The maximum depth for reef-building corals was assumed to be about 150 m, since light levels below this depth are not adequate to support photosynthesis. Recently, though, ocean explorers have discovered extensive mounds of living coral in depths from 400 m to 700 m – depths at which there

is virtually no light at all! These deep-water corals do not contain zooxanthellae, and do not build the same types of reef that are produced by shallow-water corals. But branches of deep-water coral species such as *Lophelia pertusa* grow on mounds of dead coral branches that can be several meters deep and hundreds of meters long. Recent studies indicate that the diversity of species in deep-water coral ecosystems may be comparable to that of coral reefs in shallow waters, and that there are just as many species of deep-water corals (slightly more, in fact) as there are species of shallow-water corals.

Because of the high species diversity found on shallow- and deep-water reefs, these ecosystems are proving to be very promising sources of powerful new antibiotic, anti-cancer and anti-inflammatory drugs. In addition, these reefs provide habitat for important food resources, and shallow reefs are an important part of coastal recreation and tourism industries and protect shorelines from erosion and storm damage. Despite the direct importance of coral reefs to many aspects of human well-being, shallow- and deep-water reefs are both threatened by human activities. Shallow-water reefs are damaged by sewage, chemical pollution, careless tourists, boat anchors, and abnormally high temperatures that result in thermal stress. Commercial fisheries, particularly fisheries that use trawling gear, cause severe damage to both shallow and deep-water habitats. Deep-sea coral communities can also be damaged by oil and mineral exploration, ocean dumping, and unregulated collecting.

Around the world, shallow water coral reefs have been intensively studied by scientists using self-contained underwater breathing (SCUBA) equipment, while deep coral systems are being investigated with submersibles and remotely operated underwater vehicles (ROVs). Recent explorations have found a third type of coral ecosystem between depths of 50 m and 150 m: light-limited deep reefs living in what coral ecologists call

the “twilight zone” (these areas are also referred to as “deep fore reefs” because they represent the most seaward portion of a reef). These reefs have been studied much less than shallow and deep-water reefs because they are beyond the safe range of conventional SCUBA equipment, yet are too shallow and close to shore to justify the use of expensive submersibles and ROVs. The few studies of twilight zone reefs suggest that these ecosystems not only include species unique to this depth range, but may also provide important refuges and nursery habitats for corals and fishes that inhabit shallower reefs. This is particularly important in areas where shallow reefs are severely stressed, since twilight zone coral ecosystems may provide a natural option for recovery.

Scientific exploration of twilight zone coral reef ecosystems is urgently needed to provide information for their protection, as well as to identify potentially important sources of drugs and other biological products from organisms that are endemic to these systems. Helping to meet this need is the primary focus of the 2007 Ocean Explorer Cayman Island Twilight Zone Expedition. In this lesson, students will learn about some sources of data on coral reefs, and will have hands-on experience with manipulating and interpreting some of these data.

LEARNING PROCEDURE

1. To prepare for this lesson:
 - Review the introductory essays for the 2007 Cayman Island Twilight Zone Expedition at <http://oceanexplorer.noaa.gov/explorations/07twilightzone/welcome.html>
 - Review instructions and Web site contents provided in the “Coral Habitat Data Worksheet”.

Depending upon the quality of Internet connections and printing equipment available to students, you may want to download the PDF files for the maps that will be assigned to students (Step 3), and possibly print the images

in advance. Each file is approximately 16 Mb, and the maps are approximately 8.5" x 16.5." Notice that each map file contains four layers:

- "Zone" which shows the boundaries of various coral reef zones;
- "Geomorphological Structure" which shows geological structures;
- "Biological Cover" which shows the distribution of coral, algae, and sea grasses; and
- "Background" which shows adjacent land area.

The first three layers can be made visible or invisible by clicking in the box to the left of the layer name in the "Layers" window on the left. The Background layer is locked and is always visible. The key window on the right shows the meaning of the colors and patterns used for each layer. Decide which layers you want students to analyze (Geomorphological Structure, Biological Cover, or both), and make copies of the necessary maps if students will not have access to adequate printing equipment.

- If you are not already familiar with coral reefs, you may also want to review the coral reef tutorials at http://oceanservice.noaa.gov/education/tutorial_corals/welcome.html, and http://oceanexplorer.noaa.gov/explorations/islands01/background/islands/sup10_lophelia.html for more background on *Lophelia* reefs.

A somewhat more sophisticated alternative to using the transparent grid to quantify coral habitats is to have your students use an image analysis program such as NIH Image (available at no cost from <http://rsb.info.nih.gov/nih-image/>). Details for using this program are included in the National Ocean Service Discovery Classroom lesson, "Who Has the Data?" (11 pages, 352kb; <http://oceanservice.noaa.gov/education/lessons/whohasdata.html>).

2. Briefly review and contrast shallow- and deep-water coral reefs. You may want to show part or all of a video by Peter Etnoyer from the 2002 Ocean Explorer Gulf of Alaska Expedition, which includes many images of deep-water corals (http://www.oceanexplorer.noaa.gov/explorations/02alaska/logs/summary/media/movies/deepsea-coral_video.html).

Discuss the importance of coral reefs, and reasons that they are threatened. You may want to mention the purpose and activities of the U. S. Coral Reef Task Force (visit <http://coralreef.gov/> for more information). Discuss the importance of monitoring to identify threatened reef areas and to improve understanding of reef ecosystems.

3. Tell students that their assignment is to use online data tools to investigate nearshore coral reef habitats around Molokai Island, Hawaii. Assign each student group one of the map frames (89 – 105) on the "Molokai Maps" page (http://ccma.nos.noaa.gov/products/biogeography/hawaii_cd_07/htm/maps/maps_molokai.aspx).

Provide each student group with a "Coral Habitat Data Worksheet." If you have made the necessary printouts from the map files, instruct students to ignore Step 1. Have each student group complete the tasks described on the Worksheet.

4. Lead a discussion of students' results. Students should realize that a primary purpose of habitat surveys is to establish baselines that can be compared with subsequent surveys to detect changes in coral reef systems. Discuss the variability of habitats around Molokai Island. Students should recognize that there often is considerable variability among habitats, even though the habitats are in the same geographic area.

An important part of developing a comprehensive understanding of coral reef ecosystems is knowing how reefs change over time in response to various

types of environmental change. Particularly striking is the difference between nearshore habitats on the southwestern end of the island compared to habitats on the northeastern end. Ask students to speculate on possible reasons for these differences. Images of adjacent land in the two areas show striking differences in topography; the northeastern coast is much more rugged and appears more heavily eroded than the southwestern coast.

Remind students that heavy sediment loads are often detrimental to reef-building corals. Students may also speculate that volcanic activity may be involved. Molokai was formed by two volcanoes: West Molokai (also called Mauna Loa) on the western half of the island East Molokai (also known as Wailau) on the eastern two-thirds of Molokai. Much of the East Molokai volcano grew below sea level. In addition, parts of this volcano have collapsed in giant landslides, which contribute to the heavily eroded appearance as well as the influx of sediment to adjacent coastal waters. Some pieces of landslide debris are so large that they have been given individual names as seamounts.

THE BRIDGE CONNECTION

www.vims.edu/bridge/ – Click on “Ocean Science Topics” in the navigation menu to the left, then “Habitats,” then “Coastal”, then “Coral Reef.”

THE “ME” CONNECTION

Have students write a short essay on why coral reefs are personally important and specific actions that individuals might take to reduce threats to coral reef systems.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Mathematics

EVALUATION

Written reports and discussions in Steps 3 and 4 provide opportunities for assessment.

EXTENSIONS

1. Visit <http://oceanexplorer.noaa.gov/explorations/07twilightzone/welcome.html> to keep up to date with the latest Cayman Island Twilight Zone Expedition discoveries, and to find out what researchers are learning about deep fore reef communities.
2. Online data and tools introduced in this activity can be used for a wide variety of additional activities related to coral reefs and coral reef management. Many of these data and tools can be accessed through “Discover NOAA’s Data” at the CoRIS home page (<http://coris.noaa.gov/>) and the “Corals Roadmap to Resources” (http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html). The National Ocean Service Coral Reef Discovery Kit (<http://oceanservice.noaa.gov/education/kits/corals/welcome.html>) also contains a variety of other coral reef-related lessons, information, and activities.

MULTIMEDIA LEARNING OBJECTS

<http://www.learningdemo.com/noaa/> – Click on the links to Lessons 3 and 12 for interactive multimedia presentations and Learning Activities on deep-sea corals and biotechnology.

OTHER RELEVANT LESSON PLANS FROM NOAA’S OCEAN EXPLORATION PROGRAM

History’s Thermometers [http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/thermo9_12.pdf] (5 pages, 80k) (from the 2002 Alaska Seamount Expedition)

Focus: Use of deep-water corals be used to determine long-term patterns of climate change (Physics)

Students will be able to explain the concept of paleoclimatological proxies, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about climate and climate change in the geologic past.

Cut-off Genes [<http://oceanexplorer.noaa.gov/explorations/04mountains/background/edu/media/MTS04.genes.pdf>] (12 pages, 648k) (from the Mountains in the Sea 2004 Expedition)

Focus: Gene sequencing and phylogenetic expressions (Life Science)

In this activity, students will be able to explain the concept of gene-sequence analysis; and, given gene sequence data, will be able to draw inferences about phylogenetic similarities of different organisms.

Feeding in the Flow [<http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cbfeedflow.pdf>] (6 pages, 268k) (from the 2003 Charleston Bump Expedition)

Focus: Effect of water currents on feeding efficiency in corals (Life Science)

In this activity, students will be able to describe at least two ways in which current flow may affect the feeding efficiency of particle-feeding organisms and explain how interactions between current flow and the morphology of a particle-feeding organism may affect the organism's feeding efficiency. Students will also be able to identify at least two environmental factors in addition to current flow that may affect the morphology of reef-building corals.

Cool Corals [<http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/cool.pdf>] (7 pages, 476k) (from the 2003 Life on the Edge Expedition)

Focus: Biology and ecology of *Lophelia* corals (Life Science)

Students will describe the basic morphology of *Lophelia* corals and explain the significance of these organisms, interpret preliminary observations on the behavior of *Lophelia* polyps, and

infer possible explanations for these observations. Students will also discuss why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

Keep It Complex! [http://oceanexplorer.noaa.gov/explorations/03bump/background/education/media/03cb_complex.pdf] (5 pages, 272k) (from The Charleston Bump 2003 Expedition)

Focus: Effects of habitat complexity on biological diversity (Life Science)

In this activity, students will be able to describe the significance of complexity in benthic habitats to organisms that live in these habitats and will describe at least three attributes of benthic habitats that can increase the physical complexity of these habitats. Students will also be able to give examples of organisms that increase the structural complexity of their communities and infer and explain relationships between species diversity and habitat complexity in benthic communities.

Are You Related? [http://oceanexplorer.noaa.gov/explorations/05deepcorals/background/edu/media/05deepcorals_related.pdf] (11 pages, 465k) (from the Florida Coast Deep Corals 2005 Expedition)

Focus: Molecular genetics of deepwater corals (Life Science)

Students will define "microsatellite markers" and explain how they may be used to identify different populations and species, explain two definitions of "species," and describe processes that result in speciation. Students will also use microsatellite data to make inferences about populations of deep-sea corals.

How Does Your (Coral) Garden Grow? [http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_growth.pdf] (6 pages, 456k) (from the Gulf of Mexico Deep Sea Habitats 2003 Expedition)

Focus: Growth rate estimates based on isotope ratios (Life Science/Chemistry)

In this activity, students will identify and briefly explain two methods for estimating the age of hard corals, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about the growth rate of deep-sea corals.

How Diverse is That? [http://oceanexplorer.noaa.gov/explorations/03windows/background/education/media/03win_hdiverse.pdf] (6 pages, 552k) (from the 2003 Windows to the Deep Expedition)

Focus: Quantifying biological diversity (Life Science)

Students will be able to discuss the meaning of biological diversity and will be able to compare and contrast the concepts of variety and relative abundance as they relate to biological diversity. Given abundance and distribution data of species in two communities, students will be able to calculate an appropriate numeric indicator that describes the biological diversity of these communities.

OTHER LINKS AND RESOURCES

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.
<http://oceanexplorer.noaa.gov> – Web site for NOAA's Ocean Exploration program

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer image gallery

http://oceansonline.com/encyclopedia/benthic_cnidaria.html – "The Benthic Cnidaria" from the Encyclopedia of the Sea at ExploreWorldOcean.com

<http://www.calacademy.org/research/izg/calwildfall2000.pdf> – Article from California Wild: "Stinging Seas

- Tread Softly In Tropical Waters" by Gary C. Williams; an introduction to the venomous nature of tropical cnidarians, why and how they do it

http://www.mcbl.org/publications/pub_pdfs/Deep-Sea%20Coral%20issue%20of%20Current.pdf – A special issue of Current: the Journal of Marine Education on deep-sea corals.

<http://www.mesa.edu.au/friends/seashores/> – "Life on Australian Seashores" by Keith Davey on the Marine Education Society of Australasia Web site, with an easy introduction to Cnidaria, including their method of reproduction

http://www.marinebiotech.org/dfsindex_activity.html – Detailed information about drugs from the sea

<http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html> – Introduction to Cnidaria from the University of California Museum of Paleontology

<http://www.woodrow.org/teachers/bi/1993/> – Background and activities from the 1993 Woodrow Wilson Biology Institute on biotechnology

Maxwell, S. 2005. An Aquatic Pharmacy: The Biomedical Potential of the Deep Sea. Current 21(4):31-32; available online at http://www.mcbl.org/what/what_pdfs/Current_Magazine/Pharmacy.pdf

Frame, C. and H. Gillelan. 2005. Threats to deep-sea corals and their conservation in U.S. waters. Current 21(4):46-47; available online at http://www.mcbl.org/what/what_pdfs/Current_Magazine/Threats_Conservation.pdf

Morgan, L. E. 2005. What are deep-sea corals? Current 21(4):2-4; available online at http://www.mcbl.org/what/what_pdfs/Current_Magazine/What_are_DSC.pdf

Pickrell, J. 2004. Trawlers Destroying Deep-Sea Reefs, Scientists Say. National Geographic News. http://news.nationalgeographic.com/news/2004/02/0219_040219_seacorals.html

Reed, J. K. and S. W. Ross. 2005. Deep-water reefs off the southeastern U.S.: Recent discoveries and research. *Current* 21(4):33-37; available online at http://www.mcbl.org/what/what_pdfs/Current_Magazine/Southeastern_US.pdf

Roberts, S. and M. Hirshfield. Deep Sea Corals: Out of sight but no longer out of mind. http://www.oceana.org/fileadmin/oceana/uploads/reports/oceana_coral_report_final.pdf — Background on deep-water coral reefs

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science

- Interdependence of organisms

Content Standard D: Earth and Space Science

- Geochemical cycles

Content Standard E: Science and Technology

- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

Essential Principle 1.

The Earth has one big ocean with many features.

- *Fundamental Concept h.* Although the ocean is large, it is finite and resources are limited.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

- *Fundamental Concept e.* The ocean is three-dimensional, offering vast living space and

diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

- *Fundamental Concept f.* Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is “patchy.” Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

- *Fundamental Concept b.* From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation’s economy, serves as a highway for transportation of goods and people, and plays a role in national security.
- *Fundamental Concept c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *Fundamental Concept e.* Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
- *Fundamental Concept g.* Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.

The ocean is largely unexplored.

- *Fundamental Concept a.* The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation’s explorers and researchers, where they will find great opportunities for inquiry and investigation.
- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *Fundamental Concept c.* Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
- *Fundamental Concept d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *Fundamental Concept f.* Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

SEND US YOUR FEEDBACK

We value your feedback on this lesson.

Please send your comments to:

oceaneducation@noaa.gov

FOR MORE INFORMATION

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Problem links updated May 2011.

Student Handout

Coral Habitat Data Worksheet

1. Obtain a map of benthic habitats for your assigned area:
 - a. Navigate to http://ccma.nos.noaa.gov/products/biogeography/hawaii_cd_07/htm/maps/maps_molokai.aspx. This is an index page for benthic habitats around Molokai Island, and is part of the Shallow-Water Benthic Habitats of the Main Hawaiian Islands project from NOAA's Center for Coastal Monitoring and Assessment.
 - b. In the "Molokai Maps" box, click inside the frame that was assigned to your group, to download a PDF file that contains information about benthic habitats in the area enclosed by the frame. When you open this file, you should see a large map with two smaller windows on the right and left. Information on the map is organized into layers. Each layer is listed in the "Layers" window on the left, and contains a certain type of information:
 - The "Zone" layer shows the boundaries of various coral reef zones;
 - The "Geomorphological Structure" layer shows geological structures;
 - The "Biological Cover" layer shows the distribution of coral, algae, and sea grasses; and
 - The "Background" layer shows adjacent land area.The first three layers can be made visible or invisible by clicking in the box to the left of the layer name. The Background layer is locked and is always visible. The window on the right shows the meaning of the colors and patterns used for each layer. Print the layers assigned by your teacher on a color printer. If you are able to print onto 11" x 17" (tabloid) size paper, be sure to select "None" in the "Page Scaling" window in the Print dialogue box. If you need to use a smaller size paper, select "Tile All Pages" in the "Page Scaling" window in the Print dialogue box. The maps must be printed full size in order for the "Habitat Analysis Grid" to work properly.
2. Using the transparent "Habitat Analysis Grid," count the number of grid squares occupied by each Geomorphological Structure or Biological Cover type as instructed by your teacher. Each grid square corresponds to an area of approximately 0.01 square kilometers.
3. Make a table and pie charts summarizing these data.

Student Handout

Habitat Analysis Grid

(one square represents approximately 0.01 km²)

